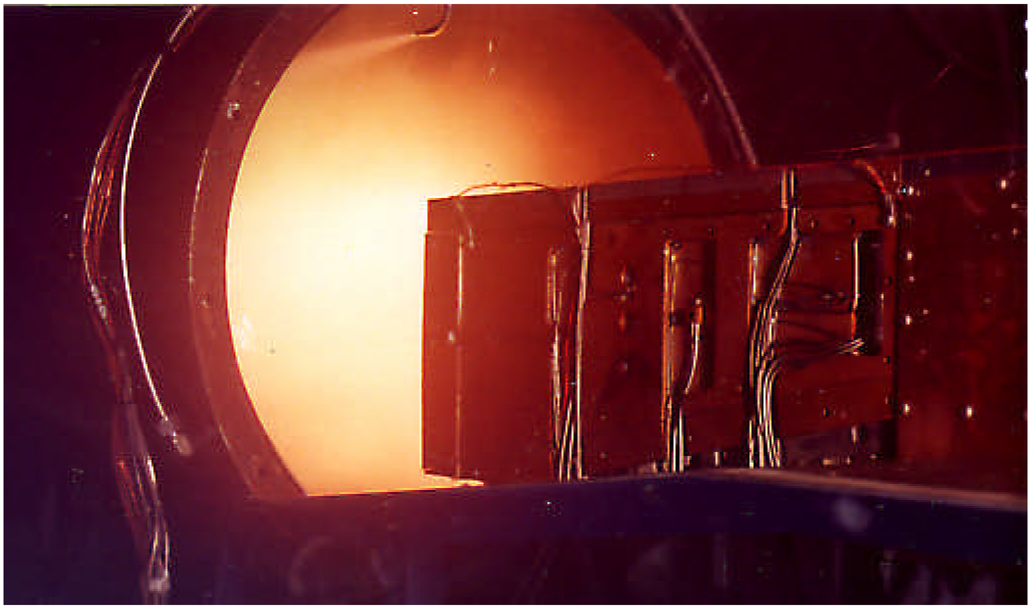
High-Temperature Polymer Composites Studied for Space Propulsion Applications



Combustion chamber on a rocket-based combined-cycle demonstrator.

Polyimide composites are being used in lightweight support structures designed to preserve the flow geometry within thin shell combustion chambers of future space launch propulsion systems. The flexible shell chamber is a rectangular metallic tube (as shown in the photograph). Principles of lightweight design and innovative manufacturing techniques have yielded an asymmetric sandwich structure that can sustain the applied thermal, acoustic, and pressure loads. The Boeing-Rocketdyne-designed thin-wall inner shell contains cooling channels that transport heat and maintain component temperature. Titanium honeycomb is bonded to the metal inner shell, and the outer surface is faced with a thin carbon fiber polyimide skin. Whereas the continuous carbon fiber enables a laminated skin of high specific stiffness, the polyimide matrix resin ensures that the rigidity and durability is maintained at high temperatures. As a supporting engine flow path structure, strong flexural rigidity is required since deflections and distortions due to operation loading are held to strict limits. Significant weight savings (~30 wt%) over the all-metal support structure are expected.

The prototype structure is the result of ongoing collaboration between the Boeing Company and the NASA Glenn Research Center seeking to introduce polyimide composites to the harsh environmental loads familiar to space launch propulsion systems. Thermal, physical, and mechanical properties of the composites and sandwich structures were studied over a range of hygrothermal states. A variety of graphite fiber architectures (unidirectional, woven fabrics, triaxially braided, and stitch patterns) were examined to optimize the component design. Several in-service exposure simulation tests-such as isothermal biaxial loading, plate flexure, thermal mechanical fatigue, rapid heating hygrothermal cycling, and combinations of these experiments-will verify the durability of high-temperature polymer matrix composites in reusable space vehicle propulsion structures.

Design tradeoff analyses were carried out using relevant closed-form solutions and approximations for high-temperature polymer composites in sandwich beams and panels. Analyses confirm that significant thermal stresses exist when materials whose coefficients of thermal expansion (CTEs) differ by a factor of 10 are combined (such as a polymer composite and titanium and steel structures). A full-scale combustion chamber support structure will be hot-fire tested on the basis of the composite sandwich structure's stress analysis, performance, and durability data.

Find out more about the research of Glenn's Polymers Branch http://www.grc.nasa.gov/WWW/MDWeb/5150/Polymers.html.

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